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ABSTRACT

There are many significant issues that need to be addressed for the future of computer-mediated communication (CMC) in education. These include: the primary benefits of CMC technology in the past; the activity structures which are supported by computer-based collaboration; technological, social, institutional and cognitive barriers which prevent CMC technologies from working; theoretical perspectives that help explain how CMC might facilitate learning; and how to address equity issues in networking. These papers, a session overview and position statements, are from a symposium which examined these issues in light of previous approaches to collaborating or communicating via computers in education. In addition to the title paper, the following position papers address the topic of CMC in education: "Networked Learning: What Have We Learned and What Does it Mean?" (Linda Harasim); "Scaffolding Communication for Learning Through Structured Media" (Christopher Hoadley); "Better Computer-Mediated Collaboration through Improved Social Contexts and Partnerships" (Sherry Hsi); "Education and Society in the 21st Century: Networks, Diversity and Mediation" (Jim Levin); and "Networked Communities Focused on Knowledge Advancement (Marlene Scardamalia). Contains approximately 50 references in all. (AEF)

# Collaboration, Communication, and Computers: What do we think we know about networks and learning?

## Session Overview and Position Statements

Interactive Symposium

AERA 1997, Chicago, IL





**Chair:** Barry Fishman, Northwestern University
**Discussant:** Marcia Linn, University of California at Berkeley

**Panelists:** Linda Harasim, Simon Fraser University
Christopher Hoadley, University of California at Berkeley
Sherry Hsi, University of California at Berkeley
Jim Levin, University of Illinois at Urbana-Champaign
Roy Pea, SRI International
Marlene Scardamalia, OISE, University of Toronto

# Collaboration, Communication, and Computers: What do we think we know about networks and learning?

**Organizers: Barry Fishman & Christopher Hoadley**
**Discussant: Marcia Linn**

**Interactive Symposium, Division C, Section 4 (Learning Environments)**

## PURPOSE

There has been an explosion of interest in computer networks for learning in the past five years, particularly in the Internet and the World Wide Web. For at least the past ten years, educational researchers have been studying this new medium and its potential for supporting educational activity in all its many forms. This session is intended to be a "pulse check" on research in educational networking. The panelists, having asked many of the original research questions in this domain, are uniquely qualified to now take stock of their (and others') work to date. The audience will also be strongly encouraged to ask challenging questions about what we now know about networks and learning.

## BACKGROUND

Three factors have led to recent interest in using computer networks to allow students to communicate, often across great distances. First, applications of technology that attempted to remove other students, teachers, and other people from the learning setting were frequently disappointing or limiting. In practice, teachers often would have groups of students interacting with computers, not only because of limited availability but also to enhance learning. Secondly, the adoption of computer-based communication technologies in business has both allowed networking technology to become economically viable and has spurred research in collaboration technology, the so-called "groupware" applications. Third, the rise of collaborative learning and social theories of learning have emphasized interpersonal contact and the social context of learning. Computers are attractive for implementing collaborative learning, in part because computers allow students to interact with others in a way traditional school settings would not. They are also attractive as a basis for collaboration, providing shared artifacts for students to discuss or work together on.

In education, computer-mediated communication has taken many forms. Some have used technologies like email or text-based teleconferencing to bring together geographically dispersed students (Hiltz, 1990; Riel & Levin, 1990; Songer, 1995). Technological advances have allowed this to expand into telepresence applications, including video teleconferencing, shared workspaces, and virtual reality (Bly, Harrison & Irwin, 1993; Fetterman, 1996; Means et al., 1994; Streitz, 1994). These applications often have an explicit focus on community building. (Brown et al., 1993; Brown & Campione, 1990; Scardamalia & Bereiter, 1991) Others have used hypertext, multimedia, and databases to allow collaborative knowledge-building and construction of shared knowledge artifacts. (Gomez et al., 1995; Scardamalia & Bereiter, 1992; Spoehr, 1994) Some have proposed using computer programming environments as a precise and expressive medium for creating and sharing models of the world (Papert, 1980; Sherin, diSessa & Hammer, 1993). Many have used the structure of these communication tools to scaffold specific interactional processes or domain-specific tasks (Conklin & Begeman, 1989; Hoadley, Hsi & Berman, 1995).

Important questions remain for the future of computer-mediated communication in education. What have been the primary benefits of computer communication technology in the past? Which activity structures are supported by computer-based collaboration? What barriers—technological, social, institutional, and cognitive—prevent communication technologies from working? What theoretical perspectives help us explain how computer-mediated communication might facilitate learning? How can we address equity issues in networking (or does one need to address them at all)?

The purpose of this symposium is to examine these questions in light of previous approaches to collaborating or communicating with others via computers in education.

## PARTICIPANTS

Barry Fishman is a research scientist and faculty member in the Learning Sciences at Northwestern University. He is currently director of the Learning Through Collaborative Visualization Project and a local team leader of Reality-Based Learning Challenge Grant, and conducts research on communication and collaboration in a broad range of classroom settings. In the past, his research has focused on use of collaborative groupware, hypertext and hypermedia systems, and desktop videoconferencing tools. His primary interest is in the design of learning environments to bridge communities of practice supported by these and other CMC technologies.

Linda Harasim is a professor of communication at Simon Fraser University and has been active for over a decade in researching educational applications of computer networking. She has designed, implemented, and evaluated networking applications in Canada, the U.S., and Latin America. Professor Harasim is currently leader of the recently awarded TeleLearning Research Network which focuses primarily on the design and development of new pedagogies and network technologies to support collaborative learning, knowledge building, and lifelong learning. She is also leading the Virtual-U Project, one of the first networked multimedia learning systems in the world that is customized for course delivery and course enhancement at all levels of education. Professor Harasim teaches about topics related to design and application of network learning environments and conducts most of her work on-line.

Christopher M. Hoadley is a Ph.D. candidate in the interdepartmental Graduate Group in Science and Math Education (SESAME) at the University of California at Berkeley. He holds degrees in Brain and Cognitive Sciences from MIT and Computer Science from Berkeley. Hoadley's work has focused on development of multimedia collaborative learning environments. He conducts research in education, computer-human interaction and cognition, and has developed a theory of instructional design through "socially relevant representations". His software has been used in college courses, middle schools, and museums nationwide.

Sherry Hsi is a Ph.D. candidate in Science Education at the University of California at Berkeley. She holds a B.S. in engineering science and an M.S. in mechanical engineering. Her interests include multimedia interface design, evaluation of interactive learning environments, engineering education, and gender issues. Her dissertation research investigates how to design collaborative electronic discussions and how students learn through scientific discourse in middle school science.

Jim Levin is a professor of education at the University of Illinois at Urbana-Champaign. He has studied the uses of networks to support learning for over 15 years. He currently heads the teaching teleapprenticeship project and examines the role of mediators in supporting learning. The range of mediators is similar in some ways to the mediators

needed in more conventional learning environments, but there are also important differences. The distribution of mediator roles also changes given new technologies, with roles distributed in space and time in ways not previously possible. In this interactive symposium, I would like to raise the issue of the mediator roles in a functioning learning community, the redistribution of these roles across distributed human and technology-based agents, and the issues of providing institutional support for these roles so that they are sustainable and scalable.

Marcia C. Linn is Professor of mathematics, science and technology education and Director of the campus-wide Instructional Technology Program at the University of California, Berkeley. Linn has pioneered in design, implementation, and interpretation of research on instruction developing a "partnership" model for research and a "scaffolded knowledge integration" framework for instruction. She has studied the role of technology in the science classroom for more than ten years in the Computer as Learning Partner project. Linn has recently shown that the gap in performance in science and mathematics between males and females is closing. Linn's most recent work takes advantage of Internet resources to improve science learning. She heads the Knowledge Integration Environment group, an Internet-based science education research project.

Roy D. Pea is the director of the Educational Technologies Group of SRI International in Menlo Park, CA. Previously, he was Dean of the School of Education and Social Policy at Northwestern University where he was the founder and Chair of the Learning Sciences Ph.D. program. Dr. Pea is a cognitive scientist with special interests in interests in integrating research and design of effective learning environments for science, programming, and multimedia computing. Dr. Pea has published "Mirrors of Minds: Patterns of Experience in Educational Computing," with K.S. Sheingold, in addition to several articles and book chapters focusing on computer-based learning and teaching environments. He is a Co-PI of the Learning Through Collaborative Visualization Project.

Marlene Scardamalia is a professor at the Ontario Institute for Studies in Education, University of Toronto, where she has been Head of the Center for Applied Cognitive Science. She has done research and published in the areas of cognitive development, psychology of writing, intentional learning, and educational uses of computers. For the past decade she has worked on the design of Computer Supported Intentional Learning Environments (CSILE). CSILE is the first network system to provide general support for collaborative learning and inquiry activities in school environments. It has been used in all areas of the school curriculum and with students grades one through university, and refined consistently over the 10 years of its day-to-day use.

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# Network Learning:
# What have we learned and What does it mean?

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## 1. Context setting: Lessons from the History of Network Learning

The history of network communication has spanned an incredibly short period of time, yet its potential to not just expand but to transform personal, social, professional, and educational communication is proving to be profound. I have found it both inspiring and instructive to view Network Learning today within the context of the brief lifetime of computer networking, as a means to see how far we have come in this short time frame and some of the lessons learned thus far, as well as to gain a sense of where the next steps might lead.

**1969: Arpanet begins**
- 1971: Email over distributed networks is invented
- 1972: Computer conferencing [cc] is invented
- 1978: Bulletin boards are invented
- 1989: NSFNet and the beginning of Internet
- 1992: WWW released by CERN

Computer networking, especially email over packet switched networks, began just over 25 years ago and already today, this unprecedented human invention, the Net, has over 80 million users and its growth rate remains exponential.

The history of computer networking, while a technological marvel, is nonetheless far more a social phenomenon, and arguably the first pioneers to systematically engage in socializing the network into early communities were the educators.

The vision that shaped the early Arpanet development and use cannot be overstated, but given the space constraints here I will simply outline the outcomes that today form the lessons of Network Learning.

**1977: Educators begin to integrate networking into learning**
- 1977: Networking [email & cc] used to enhance f2f courses
- 1981: First totally online course (non credit)
- 1982: First totally online program (non credit)
- 1983: Networked classroom model emerges (public schools)
- 1984: First totally online course (undergraduate)
- 1985: First totally online course (graduate)
- 1986: Emergence of PD communities
- 1987: Emergence of knowledge network models
- 1990: First statewide educational networks
- 1993: First national educational network

## A. Lessons from Two Decades of Network Learning:

What is so immediately striking is how little time it took educators to begin to appropriate the strange new powers of the Net, still then an abysmally difficult and obtuse medium, to expand and in many ways rethink education. Many of those special academics with early access to the Net for research purposes were apparently, at heart, educators who soon began to want to share the new benefits (and challenges) of the Net with their students, to explore and create new opportunities for learning.

We should not underestimate the lessons generated by two decades of educational CMC (Network Learning). While being careful not to overstate them, it is essential to appreciate the impact and implications of what this still experimental but increasingly socially accepted phenomenon has been and what it offers in future. These lessons shape many of the successful activities that characterize Network Learning today, and provide insights and guidelines for the activities of tomorrow.

First and foremost, the major lesson has been that networking for learning does work and can have profound impacts. To be able to make this simple statement and observation is the result of two decades of field experimentation and research. We have discovered over this time span that network learning can a) enhance and expand the traditional ways of teaching and learning, both f2f and distance, and perhaps more importantly that it can b) effectively provide entirely new opportunities and models for learning (and learning research).

Second, issues of design are key: educators must attend to both design of new learning models and pedagogies/approaches, and design of the (network) environments that support effective learning. Principled design, that is design based on advanced educational principles such as support for active collaborative learning, equitable access, multiple perspectives, and knowledge building, holds significant potential for constructing advanced learning activities and learning environments.

Third, we can sift and translate the lessons into specific knowledge design modalities, such as modes of use (enhanced, mixed mode, and totally online) and various pedagogic approaches (learner-centric collaboration and knowledge work, as well as teacher-centric methods like teleapprenticeship).

Fourth, Network Learning offers a conceptual and technological framework for lifelong learning. And Network Learning should be viewed as part of such a larger strategy, to reform/rethink education, expand opportunities, build learning communities and contribute to building a knowledge society.

Finally, Network Learning provides and requires new research opportunities to expand our study and appreciation of knowledge work, learning sciences, and conceptual change. We need new methodologies to understand what is new in new media for learning.

## B. The focus of my research in CMC and education has been...

The focus of my research in CMC over the past 15 years has been in the post-secondary environment, especially the design of online undergraduate and graduate course activity, that can support collaborative learning, multiplicity, and knowledge construction. I have also engaged in developing new research models and methodologies for the study of Network Learning, most specifically hypertextual transcript analysis. I am currently developing a software environment to customize the WWW into a learning environment that specifically provides tools and scaffolds to support collaborative learning and knowledge work, primarily for the post-secondary sector (universities, colleges, workplace). This environment is called Virtual-U and we are conducting field studies of its

use in over 15 educational institutions. Finally, I lead the TeleLearning Network of Centers of Excellence, with 150 researchers drawn from educational research, social and cognitive sciences, computer science, and engineering in 30 Canadian universities. Our focus is the design of new models of learning and environments to support lifelong learning in the 21st century.

## C. The greatest challenge of the next five years for CMC in education is (or will be)..

One of the basic requirements for education in the 21st century is to prepare learners for participation in a networked, knowledge-based economy in which knowledge will be the most critical resource for social and economic development. Students will need new and different knowledge resources, skills, roles, and opportunities. All levels of education will be affected, as lifelong learning becomes not only a personal interest but a social and economic imperative in building a knowledge society.

New communication technologies such as computer networking require and enable new opportunities for teaching and learning. The past two decades of research in network learning have demonstrated important benefits: both increased access as well as enhanced opportunities for active participation in collaborative learning and knowledge building. However, the use of new technology does not by itself guarantee improved educational outcomes. There is a critical need for rethinking education, with especial focus on the need for new designs for learning as well as new designs for the technological environments that can support enhanced cognitive and socio-affective activities.

The recent introduction of the WWW and the explosion in its use underlines the interest by educators and learners in the power of the Internet; it also highlights the pressing need for new models of learning that can take advantage of the attributes of this medium and harness them for effective learning interactions. Much of the current educational use of the WWW may be characterized as publishing rather than educational activity: faculty publish their lecture notes [for students to download and read] and students publish their assignments online. This is perhaps a more efficient form of correspondence education, or a more accessible form of CAI or CBT, but it is not reconceptualizing the learning activity to support enhanced learner collaboration and interaction. It remains, rather, based on the 19th century model of passive transmission of information rather than creating new approaches and tools to support the 21st century paradigm of active knowledge building. The 'shovelware' approach to the WWW by educators is also leading to growing dissatisfaction with the passive transmission model by both faculty and students.

There is thus an urgent need for educators to reconceptualize and transform the WWW from a generic publishing environment into an environment especially customized for effective education based on powerful new principles such as collaborative learning and knowledge building. There is also a very critical need to develop new theoretical frameworks and analytical methodologies for understanding learning that build on Network Learning, and that advance educational research and the nascent learning sciences.

# Scaffolding Communication For Learning Through Structured Media

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Communication media hold promise for educational use for two main reasons. The first, that computer and communication technology enable new possibilities, received early attention. Multimedia or interactive lessons, distance education, and student publishing are three examples of technology enabling students to perform new learning activities. These activities typically involve transcending the time, place, or scale of traditional communication activities in schools. If the technology is properly used, such activities can be transformative, breaking down traditional barriers and allowing more constructivist paradigms of schooling. For example, distance learning/telepresence technologies can be used not only to deliver traditional lectures at a distance, but also to involve community members, domain experts, or others not traditionally present in the classroom.

The second, less recognized way communication media can aid learning is through structuring interactions. As has been noted by technology implementers in many realms, technologies subtly change not just what is possible, but what is easy. (Hutchins, Hollan, & Norman, 1986; Norman, 1991; Norman, 1993; Perin, 1991) Their adoption involves not just a transference of old activities to the new technology, but a mutual shaping of the tools, the tasks or activities, and the people. For instance, in a workplace the introduction of email might replicate the existing power and communication structures, or it might change them, depending in part on what the technology affords, and in part on the existing social context. When students communicate, the results can be better or worse than non-collaborative learning.(Linn & Burbules, 1993) Technology can provide scaffolding or impasses that change the way students think and interact, for better or for worse. (Linn, 1995; Shneiderman, 1992).

Communication media can be designed in such a way to encourage reflection, learning, and thoughtful participation. (Hoadley & Hsi, 1993; Hoadley, Hsi, & Berman, 1995; Scardamalia & Bereiter, 1992) Of course, the outcome is determined not only by the interface but also the social context it is embedded in. (Hsi & Hoadley, 1995; Riel & Levin, 1990) A powerful example of how interface changes can interact with social context is how the option of anonymity may enable equitable participation of disadvantaged groups (Herring, 1996; Hsi & Hoadley, 1997). Studying the relationship of interfaces and group behavior is an incredibly complex problem; not only does one have to describe individual cognition, but one must examine these effects distributed across many individuals and their environment. (Brown et al., 1993; Hutchins, 1995; Resnick, Levine, & Teasley, 1991; Rogoff, 1991; Stefik & Brown, 1989).

Designing computer interfaces for learning means deciding on the types and behavior of representations of information. Traditionally, human-computer interaction researchers and educational software designers have focused on the representation of domain area content information, like graphical displays of physics simulations or the structure of hypertext in a history database. My work focuses on the representation of social information—information that is useful in social interactions but does not directly bear on the content

domain, such as representations of identity, of turn-taking, or of group understanding. Many of these sorts of representations are what distinguish information-centered media from communication-centered media. I believe that in the coming years, we will finally discard the idea of learning by one student interacting with an "intelligent" computer, and learn that the best educational use of a computer is in helping students, teachers, mentors, experts, parents, and others teach and learn from each other.

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# Better Computer-Mediated Collaboration through Improved Social Contexts & Partnerships

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Over the past decade, computer environments have improved in their speed, bandwidth, and facility of use. Electronic communication in these environments allows teachers to deliver lectures, pose questions to their students, and monitor their current understanding from a computer. Groups of teachers who have never met tap into virtual classrooms to construct curricula, while their students meet in on-line groups to finish joint homework assignments (Besser & Bonn, 1996; Riel & Harasim, 1994; Schlager & Schank, 1996; Tinker & Haavind, in press). However, even after 10 years of experiences in computer-mediated communication, experiments in distance learning, and millions of dollars spent on building high-tech classrooms, researchers are often frustrated, but not surprised to find that students prefer instruction with a human teacher present.

New practices for using networked technologies for learning and teaching are still emerging. Computer-mediated communication depends less on the specific technology, but on the individual participants, the roles these participants play on and off the screen, and the social interactions between them.

What makes participation in an electronic medium meaningful? How do we encourage students to overcome anxieties and participate in electronic discussions? How do teachers facilitate productive discussions that are learner-centered, engaging, and reflective? How can one design the social context of learning in a virtual electronic medium?

The focus of my research in computer-mediated communication has been to understand how to design productive electronic discussion for learning in science. My dissertation research investigates the design of electronic discussion to elicit and document student ideas, support knowledge integration, and facilitate changes in students' conceptual understanding of science by using an environment called the Multimedia Forum Kiosk (MFK) (Hoadley & Hsi, 1993; Hsi, Hoadley, & Linn, 1995; Hsi & Hoadley, 1997). Middle school students, posed with a science question, generated a repertoire of scientific ideas and even entertained wrong ideas in the electronic medium. Through collaborative discourse in structured electronic discussion, peers help recognized anomalies in reasoning, revised explanations, and made progress in their conceptual understanding of science. Peer to peer interactions including question asking, requesting clarification, or elaborating ideas supported integrated understanding. Moreover, when class discussion was compared to electronic discussion in MFK, more students participated in electronic discussion and the participation in MFK was equitable by gender, unlike face to face discussions. Students had more opportunities to voice ideas and reflect on their knowledge (Hsi & Hoadley, 1997). A choice of anonymity in discussion, the asynchronous format, and limited participation by authorities provided more opportunities to participate in electronic discussion.

Based on my research so far, I believe the greatest challenge in the next five years for CMC in education will be to understand how to structure and shape the social context of learning through better design of CMCs. This includes learning how to motivate participants to contribute effectively, take risks, and sustain purposeful participation in virtual collaborations. Problems in face-to-face learning run the risk of replicating themselves in the virtual medium. Views dominated by an authority figure, lurkers who don't participate, one-way transmission of information, incoherent discussions, and lack of consensus/closure can be ameliorated with anonymity, discussion prompts, and good moderation by a facilitator.

Another challenge researchers face is how to take advantage of multimedia to structure new interactions and organize the breadth of information new participants in CMC typically encounter. Metaphors for structuring a learning context and multiple representations of discourse are needed to help organize and document previous discussion to help reduce the "signal to noise " ratio to help improve comprehension and encourage reflective thinking. What kinds of *electronic nudges* work? What kinds of representations work to help shape the social context of discussion?

Last, but not least, the key to successful computer-mediated collaboration for instruction rests on the infrastructure and support provided to teachers (and by teachers). Future development of CMC demands a good model for virtual teaching that shifts their role as "knowledge oracle" to "on-line facilitator" while participants build new literacies in using technology as a cognitive medium for deeper reflection, integrated understanding, and personal development.

Specifically, I advocate these steps for the immediate future for computer-mediated collaboration and communication research:

• Improve the social context of learning - Understand the various roles participants should play on and off the screen, and document how new social norms for on-line participation are established that ensure equity and the participation of a diversity of cultures. Discover the ingredients for "social glue" in the learning context that sustains successful on-line collaborations.

• Help support new teacher practices - Scaffold teachers while they build new competencies and literacies in using computer-mediated technology for learning. Help teachers bridge the cultural transition from classroom teacher to on-line facilitator. Develop methods to train moderators to get participants to externalize their knowledge in an electronic form either through electronic nudges or socially relevant on-line representations. Find a good model of teacher resource management that makes computer-mediated communication a natural part of their everyday activity.

• Develop better tools for CMC through multidisciplinary partnerships - Get cross-trained cognitivists to work with computer scientists and technologists to incorporate CMC research findings into new tools. Tools to support meaningful curricular activities and good content should be informed by cognitive research before networked learning is driven by goals of just commercial institutions serving on-line propaganda.

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# Education & society in the 21st Century: Networks, diversity and mediation

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## 1. From my perspective, the most significant lesson (or accomplishment) of the past decade in CMC research is...

There are two main lessons that we've learned from the past decade of research:

- networks turn diversity into a resource rather than a problem
- mediators, both human and machine-based, are crucial for productive interaction

In many face-to-face settings, especially educational settings, diversity serves as a set of problems. With a highly diverse set of participants, it is hard to establish and maintain productive interactions. Age differences, ability differences, cultural differences, language differences all create their own problems for teachers and students. However, with networks and the diversity of new media for interaction, it is possible to have diverse sets of participants interact, and in fact, the diversity can serve as a resource rather than a barrier to interaction. By building interaction around aspects that have some shared components but also components that differ, the participants can build on the shared components and use the differing ones as a powerful source of ideas for problem solving and growth.

Another important lesson is the crucial importance of mediators in creating and sustaining productive interactions. The new interactional media created by networks require new mediator roles, as well as some of the existing roles needed in more conventional media. If these mediators are not present or are not institutionally supported, then productive interaction will not be supported, will not be sustainable over time, and cannot be expanded to a wider scale.

## 2. The focus of my research in CMC and education has been...

The focus on my research has been on developing and evaluating new interactional frameworks for learning, frameworks that create sustainable and scalable interactions that benefit all the participants. New media allow new kinds of interaction, but these new interactions require new kinds of interactions between a modified set of participants. The roles that are important in more conventional learning environments change. Some roles are redistributed to different people, some roles become less important, and new roles emerge as critical. We have been particularly interested in new frameworks that cross the previous boundaries that have separated education from the rest of society, that allow students to learn within the context of activity outside of classrooms and schools. These new frameworks are effective only when the critical roles are supported in a scalable and sustainable way.

## 3. The greatest challenge of the next five years for CMC in education is (or will be)...

The greatest challenge will be in exploring new relationships between education and the rest of society. The barriers that have previously isolated schooling from the rest of society are being broken down, and we need to develop ways to support effective new interactional frameworks to support learning in these new environments that integrate learning and doing. We need to explore the range of possible relationships, evaluate them to determine which support the kinds of learning that will be powerful in our changing world, and then determine what kinds of support are needed to allow us to sustain and expand the use of these frameworks by the full range of learners.

# Networked Communities Focused on Knowledge Advancement

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A hallmark of student engagement in educational networks is the production of knowledge of value to others, not simply demonstrations of personal achievement. For school students this means producing ideas that others find valuable, including others with more relevant experience and knowledge. This is not to say that students solve problems that remain unsolved by those more expert in their fields of inquiry, but that they explore ideas in ways that experts find engaging. Work over the last decade has demonstrated that it is possible to achieve such ends, and to do so in ways extensible to all students and to a wide variety of participants beyond the school walls. But creating such impressive contexts for knowledge advancement requires increasingly high-level work with ideas. As suggested in the brief review that follows of cognitive demands surrounding self- and group-cognition, the challenge is substantial.

Self Cognition. Flavell (1981) offered a model of cognitive monitoring highlighting metacognitive strategies used to monitor one's own cognitive activities. Brown (1987) identified two types of metacognitive knowledge: knowledge about cognition, and knowledge about regulation of cognition. Knowledge about cognition is necessary for reflecting on the products of one's cognitive activity. Knowledge about regulation of cognition is used to oversee strategic action such as planning, checking and monitoring of cognition. Karmiloff-Smith (1992) uses the term metaprocedural processes when procedures originally intended to operationalize goals become input to procedures. Mindfulness (Salomon & Perkins, 1989) is yet another term used to characterize the reflective processes that Dewey (1933) claims are central to effective education. Bereiter & Scardamalia (1989) have argued that expertise is itself an extension of the processes of intentional learners, viewed within broader social contexts (Bereiter & Scardamalia, 1993).

Group Cognition. Sociocultural cognitive research sees self-regulation arising from activity between people. Internalization of activity and ideas previously represented over different participants allows for functioning at increasingly self-sufficient levels (Vygotsky, 1978 ). Others stress the importance of community-level processes (Dunbar, 1995), in which working in community context places increasing complex demands on contributions and on what needs to be accomplished. Our own accounts of expertise focus on knowledge transformative processes that require situating ideas in communities sharing a commitment to progressive problem solving (Bereiter & Scardamalia, 1993; Scardamalia & Bereiter, 1987).

My reflections on lessons learned and greatest challenges follow from experiences in the design and evaluation of Computer-Supported Intentional Learning Environments (CSILE). We began by building a communal-database architecture to be used as a discourse medium at the heart of classroom processes. Of greatest educational significance has been the extent to which this initiative has led to a radical shift in classroom processes, moving them from a focus on task performance to public knowledge jointly constructed by students. It has also made clear that the problems to be faced are not about schooling, but

rather about rethinking society's knowledge resources and the ways in which students engage these resources, as students are able to engage in considerably more self-intentioned and high-level group processes than suggested by current literature. We have, in turn, come to see the challenge as that of moving to a "Knowledge Society" framework--a network of networks that supports interleaved communities ranging from elementary school students to advanced research institutes. This requires a level of connectedness based on shared problems of understanding. New architectures and linking mechanisms will need to be designed to achieve this. Promising possibilities include linkages across databases that allow for high-level views and means for individuals to meet based on shared problems. Such means for establishing connections contrast with simpler means such as links between sites based on topical associations and replication of contents of databases that create completely overlapping sets of material. It is easy to overwhelm participants with large amounts of material, especially when work is extended over large teams working in different contexts. It is also easy to focus attention on irrelevant material and topical connections rather than on problems of understanding. Focusing on problems of understanding and knowledge advancement represents a serious challenge.

Systems that create a public presence for ideas and for group work have the potential of creating contexts of responsibility and pride, contexts in which individual and communal achievements reinforce one another and serve to ensure and even to accelerate continual improvement. Software itself does not achieve such ends, as oftentimes noted. For example, we have seen CSILE used as a notebook or as an add-on to the normal curriculum--neither use requiring much effort nor instruction, as these uses fit easily with current school practices. But such uses also fall far short of the intended goal of making students' ideas the focus of inquiry, and the database itself an achievement that represents the best of their collective efforts.

The notion that students' ideas and resulting advances in those ideas should be centerfront in school processes--not science, mathematics, writing, or reading tasks, and not games, projects, field trips, or other activities--seems counterintuitive. How can one learn more about content if students' ideas rather than that content are the focus of inquiry? What is at issue is NOT less attention to core content or to activities that drive understanding. In contrast, we believe the lesson to be learned is that a whole new layer of activity OVER-AND-ABOVE such content and related activities is required. Only then can the self-and group-initiated processes required for sustained engagement with ideas be achieved, because only then can students take charge of processes such as identifying gaps in their understanding, proposing theories and subjecting them to critical review, engaging in emergent goal-definition, and experiencing the deep interconnectedness of fields of inquiry that result from self-initiated inquiry. Without such engagement the very high level activities that are typically the exclusive domain of teachers and curriculum experts will remain that way.

A decade after experiments began aimed at bringing students' ideas centerfront in school processes and objects of continual refinement, we know it can work. We have strong data and exemplary classrooms, each producing databases that convey levels of knowledge building that experts find helpful for their own knowledge advancement. This is not to say that these resources represent expert-level knowledge achievements, but rather that students' contributions are so deep and reflective that they provide important new ways of viewing a field of inquiry--ways that other inquiring minds find helpful for their own efforts. Thus there is a real basis for continual refinement of ideas, as participants considerably more schooled in a domain find they can advance their own understanding at the same time they construct views of students' databases that result in increasingly effective discourse between students. With this we have the makings of win-win situations in the knowledge construction arena.

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